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# Adaptive Antennas for UMTS Microcellular Operational Environments

G.V.Tsoulos, G.E.Athanasiadou, J.P.McGeehan and M.Beach

Centre for Communications Research  
University of Bristol, Merchant Venturers Building, Room 2.19,  
Woodland Road, Bristol, BS8 1UB, UK  
tel: +44 (117) 954 5203, fax: +44 (117) 954 5206, e-mail: G.V.Tsoulos@bristol.ac.uk

## Abstract

*In order to achieve the ambitious requirements introduced for future wireless systems, new 'intelligent' or 'self-configured' and highly efficient systems will be most certainly required. In the pursuit for schemes that will solve these problems, attention has recently turned into spatial filtering methods using advanced antenna techniques; adaptive or smart antennas.*

*This contribution reports work for the application of adaptive antennas in third generation microcellular operational environments based on both simulations and field trials performed with the adaptive antenna testbed developed under the European ACTS TSUNAMI project.*

## Introduction

Third generation systems introduce increased demands for Quality, Mobility and Spectrum Efficiency in mobile communications systems, and thus motivate the need for new techniques, e.g. the deployment of smaller radio cells, combination of different cell types in mixed cell architectures, fixed sector or multibeam basestation antennas, as well as, spatial signal processing with adaptive (or smart) antenna arrays. With efficient use of spatial processing at a cell site, optimum receive and transmit beams can be used to improve the system's performance in terms of the available capacity and quality of service parameters. By exploiting the spatial domain via an adaptive antenna the operational benefits to the network operator can be summarised as follows [1]:

- Capacity enhancement
- Coverage extension
- Optimum-smart system planning
- More efficient power control - smart handover
- Reduced transmit power
- Smart link budget balancing

- Support of value added services
- Ability to support hierarchical cell structures

## Technical Approach

Adaptive Antennas are now regarded by many within the wireless communications industry as a core system component in future generation mobile networks. In order to promote European research and development in this strategic area, the Commission of the European Community has funded through the RACE and now the ACTS programs the TSUNAMI consortium in order to further research technological advances for the next millennium.

At first a two year (1994-1995) project with the acronym TSUNAMI was funded under the RACE funding initiative. The focus of this project was the demonstration of the SDMA technique embedded within a wireless communications system [2-4]. To achieve this goal, the consortium developed state-of-the-art component technologies, conducted numerous spatial propagation trials and performed extensive system simulations. The work of the RACE TSUNAMI project continues now under the ACTS program which is much closer to market, ("making it happen"), and is heavily focused towards the integration of this technology with DCS1800.

The RACE TSUNAMI field trials and simulation studies considered only macrocellular deployment of adaptive antenna systems, although it is well known that third generation systems will include both micro and pico-cellular environments. However, unlike previous large cell scenarios, statistical propagation models no longer provide accurate results in such environments. Due to the site specific nature of the small cell environments, the propagation models are now required to take into account the exact position, orientation and electrical properties of individual buildings. Modelling of small cell environments with Ray Tracing techniques has emerged as a dominant method. These techniques can make full

use of site specific building databases (data being obtained from sources such as the Ordnance Survey or the National Remote Sensing Centre), hence allow for the position and composition of individual buildings to be considered in detail and thus provide site specific complex channel impulse response information. The ray tracing model that is used for the microcellular simulations in the ACTS TSUNAMI project is a model that has been previously developed by the University of Bristol independently [5-6]. It represents rays in two dimensions whilst internally considering three dimensional reflections (including ground reflections), diffractions and transmissions. From the channel impulse response is possible to extract key parameters such as average power, RMS delay spread and coherence bandwidth. In addition, arrival and departure angle information for each multipath ray is inherent within the tool, as well as full polarisation analysis, thus permitting the impact of antenna orientation to be assessed. Due to the fact that ray-tracing produces deterministic channel models by processing user-defined environments (data bases), the analysis can be repeated easily for a variety of different environments. That gives the ability to produce results for the areas where the field trials for the ACTS TSUNAMI will be performed and hence be used as a complementary tool for prediction and validation, and also to extent the investigation to many different environments which is difficult to be done with field trials.

Since the core objective of the ACTS TSUNAMI project is to evaluate and develop Adaptive Antenna technologies applicable to third generation systems (UMTS/IMT-2000), it was recognised that an assessment of adaptive antenna techniques for UMTS small cell architectures is necessary. As it can be seen from figure 1, the simulator that has been developed for this reason can be separated into four basic blocks:

1. The block which generates the impulse response of the channel under investigation. Apart from the geographical data bases used from the model to simulate the different environments, input parameters include the number of reflections transmissions and diffractions, the transmitted power, antenna radiation patterns, etc. The resultant output file includes the time delay, the angle of arrival and the power of each received ray.

2. The block which simulates the operational system. For the ACTS TSUNAMI project the chosen system is DCS1800.
3. The adaptive antenna block. Here parameters include the array geometry (e.g. linear-circular), the number of antenna elements and their interelement spacing and polarisation. Several beamforming algorithms/methods will be investigated in the context of the produced output signal-to-interference ratio and radiation pattern characteristics. Parameters which affect the performance of an adaptive antenna will also be investigated.
4. Using a Monte Carlo approach the above steps of the analysis are repeated many times for different positions of users, randomly chosen. With this method the statistics (PDF, CDF, Outage) of the chosen output criteria can be generated and hence much more secure and reliable performance results can be calculated.

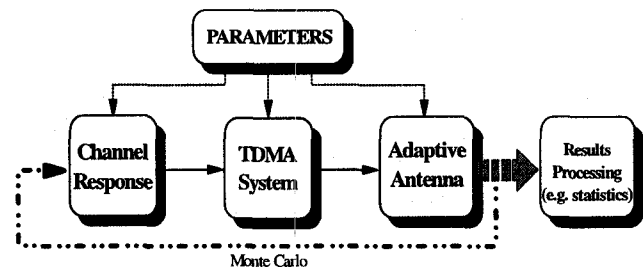


Figure 1: Simulation block diagram schematic.

The objectives from the microcellular activity of the ACTS TSUNAMI project can be summarised as follows:

- Theoretical figure of merit for the adaptive antennas in microcellular environments with TDMA systems.
- Parameters which affect the performance of an adaptive antenna in such environments.
- Comparison of the simulation results with results from the microcellular field trial campaign with the TSUNAMI II testbed.

### ACTS TSUNAMI Field Trial System

The ACTS TSUNAMI Field Trial System [7] consists of a modified DCS-1800 basestation system to which an adaptive antenna sub-system has been retro-fitted. The testbed consists of the following sub-systems.

- Separate transmit and receive eight element antenna arrays custom developed for the

project and including facilities for calibration.

- Eight DCS-1800 transceivers operating on the same carrier frequency and modified for common AGC gain control.
- Eight channel digital beamforming for transmit and receive based on the DBF1108 beamformer ASIC.
- An adaptive processing sub-system based on TMS320C40 DSPs.
- A modified DCS-1800 BTS which demodulates the signal output by the Rx beamformer network and generates the signal to be processed by the Tx beamformer network.
- A calibration subsystem for on-line calibration of the receiver and transmitter chains' amplitude and phase mismatches.
- A DCS-1800 MSC provided by the Orange National Host test network.

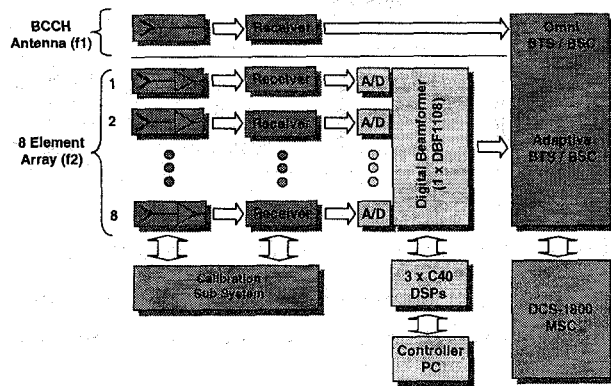


Figure 2: ACTS TSUNAMI Field Trial System Rx block diagram [7].

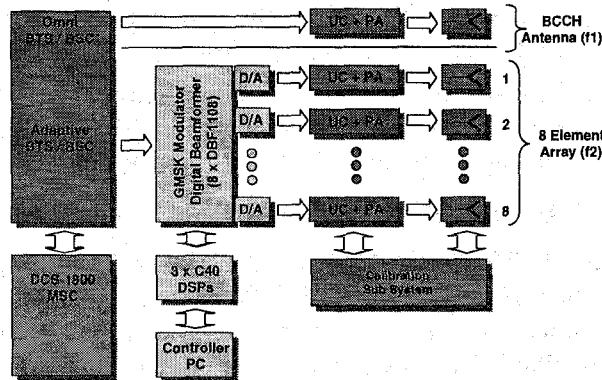


Figure 3: ACTS TSUNAMI Field Trial System Tx block diagram [7].

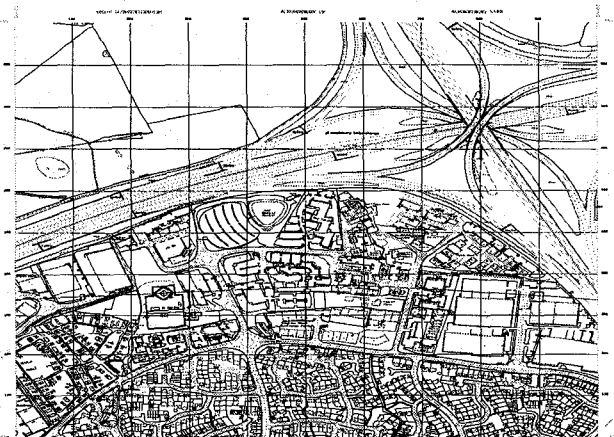
The block diagrams in figures 2 and 3 show how the equipment developed by the project partners has been combined to create the Rx and Tx paths of the field trial system.

In the receive path the beamformer operates on the analogue quadrature baseband signals produced by the DCS-1800 radios to create a digital beamformer output signal which is fed to the equaliser in the basestation. In the transmit path the unmodulated bit stream from the basestation is fed to the beamformer sub-system, where it is GMSK modulated and beamformed to produce eight quadrature baseband signals which are fed back into the DCS-1800 upconverters.

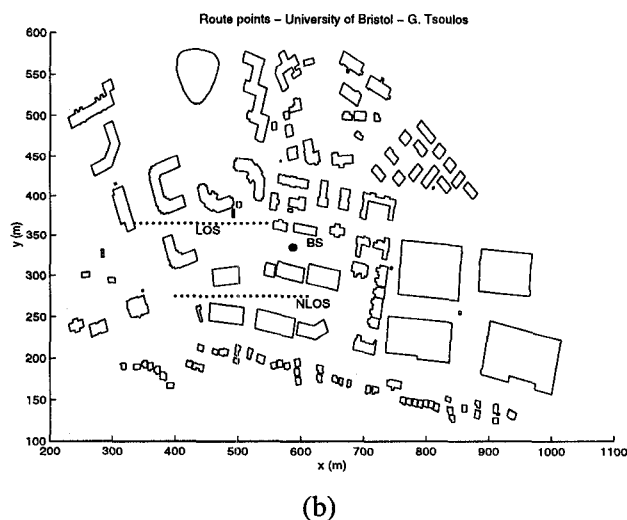
Note that the field trial system also contains a standard 'omni' (actually 120 degree sector) radio which operates on a different carrier frequency to the adaptive array and is used for the BCCH. This channel also provides a reference against which the performance of the adaptive array can be compared.

### Field Trial deployment at National Host

The field trial site is shown in figure 4. The eight element Rx and Tx arrays are mounted at a height of 7m for the microcellular trials on a tower at the Orange testbed site, in Bristol, UK. Figure 4a is a plot of all the available information in the the database. The geographical features are represented as vector data with coded structure of the line features, point detail and text information contained in a typical map (36 layers and six text categories).



(a)

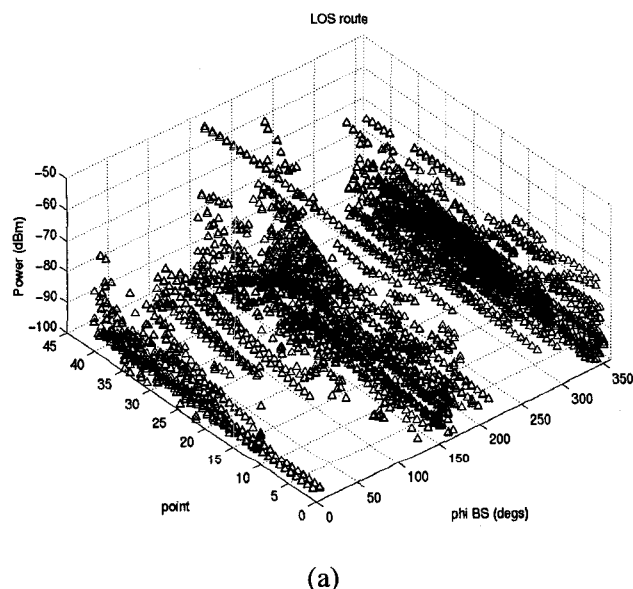


(b)  
Figure 4: a) Original, commercially available database and b) simplified database.

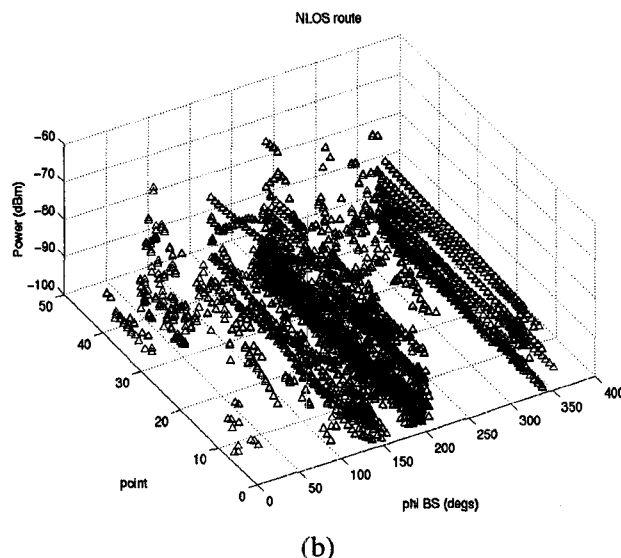
The information needed for the microcellular Ray Tracing model is only the information for the outline of the buildings and other objects, as shown in figure 4b. Figures 5 shows examples for the angles of arrival (azimuth) of the multipath rays versus their power (at the base station), for the LOS and NLOS routes shown in figure 4b. The wide scattering of the angles of arrival especially in the NLOS case, can be noticed.

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(a)



(b)  
Figure 5: Power versus azimuth angle of arrival for each multipath ray of the impulse response for the a) LOS and b) NLOS, test routes shown in figure 4b.

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